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Chapter

Effects of Morphometric Indicators on Incubation Values of Eggs and Sex of the Chicks of the Light Hen Hybrids

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Abstract

The aim of this study was to establish incubation values of eggs (egg fertilization, absolute and relative embryo mortality, and hatchability of male and female chicks), morphometric indicators (preincubation egg mass; length, width, and egg shape index; hatched female and male chicken mass and their relative share in the egg mass before incubation), and the phenotype correlation between some traits in the younger parent flock (YF_{33}—33 weeks) and the older flock (OF_{49}—49 weeks) of the light Institut de Sélection Animale (ISA) Brown hybrid. With regard to incubation values, the younger flock (YF_{33}) demonstrated better incubation results than the older flock (OF_{49}). The egg fertilization rate was 95.24 and 94.22%, respectively, chick hatchability as the percentage of the total of incubated eggs was 86.51 and 84.89%, respectively, and chick hatchability as the percentage of the total of fertilized eggs was 90.83 and 90.09%, respectively. Embryo mortality rate was 8.73 and 9.17% (YF_{33}), and 9.33 and 9.91% (OF_{49}). Regardless of the parent flock age, eggs that hatched female chicks had lower values of observed morphometric traits than those that hatched male chicks, except for the egg shape index (77.49–77.47%, respectively) which was higher by 0.02% in eggs which hatched female chicks, but this difference was not statistically significant ($P > 0.05$). Contrary to effects of the chick sex, the parent flock age had considerably larger effect on observed morphometric traits, as all morphometric indicators of eggs and hatched chicks of both sexes in the older flock (OF_{59}) had statistically significantly higher values ($P < 0.001$) than in the younger flock (YF_{33}). The only exception is the relative share of the chicken in the egg mass where the measured difference (−0.03%) was not statistically significant ($P > 0.05$). The phenotype correlation coefficients determined (r_p) between the egg mass before the incubation period and the egg shape index were statistically significant ($P < 0.01$; $P < 0001$), except between the egg mass of eggs which hatched female chicks and the egg shape index in the young flock (YF_{33}), whereby the calculated coefficient ($r_{xy} = 0.107$) was not statistically confirmed ($P > 0.05$). Furthermore, the egg mass and hatched chicken mass of both sexes increased with the age of the parent flock, and statistically significant absolute phenotype correlation ($P < 0.001$) was determined between these two indicators.

Keywords: morphometric measurements, sex, eggs, chicks

1. Introduction

Keeping, breeding, and management of the parent flock during the eggs for fertilization production period, as well as the incubation of eggs for hatching, are very specific, specialized, and complex stages of the production process. Apart from the genotype (breed, hybrid), some nongenetic factors (age of the parent flock, keeping system and diet, morphometric egg traits, egg storage period, incubation conditions) play important role in the management of the one-day chicken production of the heavy hybrid (meat) and the light type hybrid (eggs for consumption), resulting from the specifics of the poultry reproduction.

The main difference between the reproduction of the birds—poultry—and the mammals is the fact that birds do not give birth to live offspring as mammals do. Instead, the new organism develops outside of the female's uterus, in the egg. The poultry breeds by means of eggs which must be fertilized in order to produce the young—offspring. Well fertilized egg for hatching is an embryo "package" with all the necessary nutrients which facilitate its development until it's hatched and for another few days after the hatching [1].

Effects of the nongenetic factors, primarily effects of age on egg incubation values, but also effects of the egg mass, length of the storage period, mechanical and structural egg characteristics on the effective production of the one-day chicken, were extensively studied, particularly in the case of the broiler parents (heavy hen hybrids). Pure breeds and parent flocks of various light line hybrid hens were studied on a much smaller scale in this context.

Studies of Skewea et al. [1–14] were conducted, among other reasons, to demonstrate effects of age of different broiler parent flocks of various hybrids on incubation values of eggs (fertilization rate, hatchability, and the quality of one-day old chicken), as well as their phenotype correlation. The general observations would be that the egg mass and the newly hatched chicken mass increases with the age of the broiler parents; the fertilization and hatchability rate reaches its peak in the middle of the production cycle; relative share of the chick in the egg mass increases slightly with the age; and while the egg shape index in various stages of the production cycle demonstrated substantial variability. The absolute phenotype correlation between the egg mass before incubation and the one-day old chicks was determined in most of the cases, regardless of the chicken sex.

Narushin and Romanov [5, 15] point out that the egg shape index has significant effects on incubation indicators, and thus that eggs of abnormal shapes should not be used for incubation because they prevent the normal embryo development which results in increased embryo mortality during the incubation period.

This observation was confirmed by Mitrović et al. [16] who studied mechanical (physical) and incubation values of eggs of two different hen breeds (Naked Neck hen and Sombor kaporka) kept in semi-intensive keeping systems. In their study, the egg shape index was 71.01 and 72.04%, respectively, and the relative share of the chicken in the egg mas was 73.61 and 76.68%, respectively. Abanikannda and Leigh [17] report higher egg shape index in eggs which hatched male chicks (Anak and Marshall hybrids) than in eggs which hatched female chicks (75.25 and 74.53%; 76.27 and 76.00%). In case of the Ross hybrid, the egg shape index measured was 76.09% (male chicks) and 76.41% (female chicks).

In general, the literature survey shows that most of the authors studied effects of the nongenetic factors on egg incubation values and the production of one-day chicken of both sexes coming from broiler parents. This is understandable since both sexes of the heavy hybrids are used for the meat production. However, in case of light hybrids egg incubation, male chicks are generally destroyed, while female chicks are used for the breeding and the commercial egg production.

However, Lichovníková et al. [18, 19] show in their studies that the male chicks of ISA Brown and Hy-Line can be successfully used in organic production of the quality broiler meat. In line with this, studies [20–22] point out that for humane reasons and from the animal welfare aspect, the fattening of the male chicks of light line hybrids in intensive broiler meat production is not economically justified, but in extensive and semiextensive conditions and with a prolonged fattening period, it is possible to produce quality meat with a higher protein share and a lower abdominal fat percentage.

Apart from the abovementioned authors [16, 17], research studying effects of nongenetic factors on the quality of hatching eggs and on incubation results and the quality of hatched chicks of male and female one-day chicks of the parent flocks of different breeds and light line hybrids was conducted by [5, 23–28], as well as [29, 30]. Similar research, but in case of the wild/nondomesticated birds (sparrow-*Passer,* falcon-*Falco*, northern lapwing-*Vanellus vanellus*), was conducted by [31–33].

For these reasons, the main purpose of this study was to investigate the effects of light ISA Brown hybrid parent flock's age on the morphometric egg traits (egg mass, egg length and width, egg shape index, egg volume, absolute and relative egg mass loss until day 18 of incubation, hatched female and male chicks mass, chicken share in the egg mass) and the incubation values of eggs for hatching (fertilization rate and chicken hatchability), as well as determination of the phenotype correlation between more important among the observed traits.

The ultimate aim of this research was to attempt to establish the sex of the future offspring on the basis of the morphometric measurements of the mentioned pre-incubation characteristics of eggs, which would potentially allow to incubate eggs selectively in the future, that is, only those eggs which will hatch female chicks—potential laying hens producing eggs for consummation.

2. Materials and methods

The experimental part of this study—incubation of the light line ISA Brown hybrid parent flock eggs—was conducted in the incubation station of the private poultry farm "Jugokoka," in Belgrade, Serbia.

Eggs originated from the flock bred on the parent farm in an installation which housed 5000 laying hens and 620 roosters during the production phase. With the purpose to determine morphometric egg traits and incubation egg values as well as the sex of the hatched chicks, eggs were collected from both the younger flock (YF) aged 33 weeks (YF_{33}) and the older flock (OF) when the flock was 49 weeks old (OF_{49}).

In both cases, incubated eggs were 4 or 5 days old. A total of 252 eggs were randomly collected for the first incubation (YF), and 225 for the second incubation (OF)—a total of 477 eggs. All eggs were laid in incubators of equal capacities and produced by the same manufacturer. The number and percentage of fertilized eggs were recorded at each round of laying of eggs into the incubator, as well as the number and percentage of hatched chicks out of the number of incubated and fertilized eggs, the number and percentage of eggs with dead embryos, and the progression of the mass loss until day 18 of the incubation period. This means that morphometric indicators of all eggs were individually measured before these were laid into the incubator. Egg mass, length and width of each egg were measured, marked on the shell with pencil, and each egg was disinfected in formaldehyde vapors. Upon completion of the incubation period, individual mass of the newly hatched chicks, both female and male, was measured (different sexes of this breed have different feather color).

Before the eggs were laid into the incubator, following measurements were made: egg shape index and egg volume, absolute and relative egg mass loss until day 18 of incubation, and the percentage of the chicken in the egg mass (relative share of the chicken in the egg mass).

Egg shape index (ESI) was calculated according to the following formula: ESI = EW (egg width)/EL (egg length) × 100. Particular attention was given to those eggs which hatched live and healthy chicken.

Egg volume was calculated according to the formula [34]: $V = (\pi/6) \times L \times W^2$ where V = egg volume; W = egg width, L = egg length; π = constant, 3.1416.

When moved to the incubator hatching tray (day 18), eggs were individually placed in separate compartments in order to be sure which chicken was hatched from which egg. Based on the egg mass and the newly hatched chicken mass, relative share of the chicken in the egg mass was calculated, that is, chick percentage (CP) in the egg mass, according to the following formula: –CP = [(chick mass – CM)/(egg mass – EM) × 100].

Information obtained in this way was entered into a database designed by the statistical software IBM SPSS statistics Version 22 (2013). Basic data processing was conducted by applying the standard variation statistical methods (descriptive statistics): arithmetic mean ($\bar{x}$), [...] arithmetic mean error ($S_{\bar{x}}$), standard deviation (S), and variation coefficient (VC).

Difference in significance between observed morphometric traits was tested by application of the corresponding variance analysis (two-level factorial experiment—2 flock ages × 2 sexes) with uneven numbers of repetition per treatment—classes, including interaction.

Following is the mathematical model of the variance analysis:

$Y_{ijk} = \mu + FA_i + ESC + (FA \times ESC)_{ij} + e_{ijk}$,

where:

Y_{ijk}—observed morphometric value in i-flock age, of the j-egg/chick sex, and k-repetition;

μ—general mean;

FA_i—effect of i-flock age (YF_{33} and OF_{49});

ESC_j—effect j-egg sex-chick during incubation period;

$(FA \times ESC)_{ij}$—effect of interaction between i-flock age and j-chick sex;

e_{ijk}—accidental error.

Based on the variance analysis and the results of the $F_{exp.}$ values, all significant and very significant differences were graded by Tukey test. Additionally, phenotype correlation coefficients (r_p) between observed morphometric traits, primarily between the egg mass and egg shape index and other morphometric indicators, with stress on the chick's sex, were calculated according to the relevant formula.

3. Results

For the initial experiment, a total of 477 eggs for hatching were incubated in two different time periods. When the parent flocks were 33 weeks old (YF_{33}) and 49 weeks old (OF_{49}), 252 eggs taken from the younger flock (YF_{33}) and 225 eggs from the older flock (OF_{49}) were incubated.

Regardless of the age and sex of the hatched chicks, total number of fertilized eggs was 452 (94.76%), nonfertilized 25 (5.24%), and there were 43 eggs with dead embryo (9.01% out of the number of eggs incubated; 9.51% out of the number of eggs fertilized), while the total number of hatched chicks was 409 (85.74% out of incubated eggs; 90.49% out of fertilized eggs).

In general, we can conclude that the younger flock (YF_{33}) had higher incubation values than the older flock (OF_{49}) as the fertilization rate was 95.24 and 94.22%,

Indicators	$\bar{x}$	n	$S_{\bar{x}}$	S	VC
Young parent flock (YF33)					
Female chicks					
Egg mass before incubation (g)	58.06	118	0.28	3.09	5.32
Egg length (cm)	5.48	118	0.01	0.13	2.37
Egg width (cm)	4.29	118	0.01	0.11	2.56
Egg shape index (%)	78.18	118	0.10	1.13	1.44
Egg volume (cm^3)	52.82	118	0.34	3.71	7.03
Egg mass loss until day 18 of incubation (g)	6.58	118	0.04	0.48	7.29
Egg mass loss until day 18 of incubation (%)	11.34	118	0.06	0.65	5.73
One day chick mass (g)	38.80	118	0.21	2.28	5.88
Relative chick share in the egg mass (%)	66.84	118	0.14	1.49	2.23
Male chicks					
Egg mass before incubation (g)	58.83	100	0.35	3.48	5.91
Egg length (cm)	5.51	100	0.01	0.13	2.36
Egg width (cm)	4.30	100	0.01	0.11	2.56
Egg shape index (%)	78.15	100	0.09	0.94	1.20
Egg volume (cm^3)	53.51	100	0.38	3.83	7.16
Egg mass loss until day 18 of incubation (g)	6.63	100	0.05	0.53	7.94
Egg mass loss until day 18 of incubation (%)	11.28	100	0.07	0.73	6.47
One day chick mass (g)	39.57	100	0.26	2.61	6.59
Relative chick share in the egg mass (%)	67.26	100	0.18	1.84	2.74
Both sexes					
Egg mass before incubation (g)	58.41	218	0.22	3.29	5.63
Egg length (cm)	5.49	218	0.01	0.13	2.37
Egg width (cm)	4.29	218	0.01	0.11	2.56
Egg shape index (%)	78.16	218	0.07	1.05	1.34
Egg volume (cm^3)	53.14	218	0.26	3.78	7.11
Egg mass loss until day 18 of incubation (g)	6.60	218	0.03	0.50	7.58
Egg mass loss until day 18 of incubation (%)	11.31	218	0.05	0.69	6.10
One day chick mass (g)	39.15	218	0.17	2.46	6.28
Relative chick share in the egg mass (%)	67.03	218	0.11	1.67	2.49
Old parent flock (OF49)					
Female chicks					
Egg mass before incubation (g)	62.92	101	0.21	2.12	3.37
Egg length (cm)	5.71	101	0.01	0.09	1.58
Egg width (cm)	4.38	101	0.01	0.07	1.60
Egg shape index (%)	76.69	101	0.03	0.33	0.43
Egg volume (cm^3)	57.35	101	0.28	2.77	4.83
Egg mass loss until day 18 of incubation (g)	7.23	101	0.04	0.42	5.81
Egg mass loss until day 18 of incubation (%)	11.48	101	0.04	0.42	3.66
One day chick mass (g)	42.14	101	0.16	1.62	3.84
Relative chick share in the egg mass (%)	66.96	101	0.06	0.61	0.91
Male chicks					
Egg mass before incubation (g)	63.90	90	0.31	2.98	4.66
Egg length (cm)	5.73	90	0.01	0.10	1.74
Egg width (cm)	4.40	90	0.01	0.09	2.04
Egg shape index (%)	76,72	90	0.03	0.25	0.33
Egg volume (cm^3)	58.05	90	0.35	3.30	5.69
Egg mass loss until day 18 of incubation (g)	7.47	90	0.05	0.53	7.09
Egg mass loss until day 18 of incubation (%)	11.68	90	0.04	0.38	3.25
One day chick mass (g)	42.93	90	0.23	2.22	5.17
Relative chick share in the egg mass (%)	67,16	90	0,06	0,53	0,79

Indicators	$\bar{x}$	n	$S_{\bar{x}}$	S	VC
Both sexes					
Egg mass before incubation (g)	63.38	191	0.19	2.60	4.10
Egg length (cm)	5.72	191	0.01	0.10	1.75
Egg width (cm)	4.39	191	0.01	0.08	1.82
Egg shape index (%)	76.70	191	0.02	0.30	0.39
Egg volume (cm^3)	57.68	191	0.22	3.03	5.28
Egg mass loss until day 18 of incubation (g)	7.34	191	0.03	0.48	6.54
Egg mass loss until day 18 of incubation (%)	11.57	191	0.03	0.41	3.54
One day chick mass (g)	42.51	191	0.14	1.96	4.61
Relative chick share in the egg mass (%)	67.06	191	0.04	0.58	0.86
Young and old parent flock(YF33 and OF49)					
Female chicks					
Egg mass before incubation (g)	60.30	219	0.24	3.62	6.00
Egg length (cm)	5.59	219	0.01	0.16	2.86
Egg width (cm)	4.33	219	0.01	0.10	2.31
Egg shape index (%)	77.49	219	0.08	1.13	1.46
Egg volume (cm^3)	54.91	219	0.27	4.01	7.30
Egg mass loss until day 18 of incubation (g)	6.88	219	0.04	0.55	7.99
Egg mass loss until day 18 of incubation (%)	11.41	219	0.04	0.56	4.91
One day chick mass (g)	40.34	219	0.18	2.60	6.44
Relative chick share in the egg mass (%)	66.90	219	0.08	1.17	1.75
Male chicks					
Egg mass before incubation (g)	61.23	190	0.30	4.12	6.73
Egg length (cm)	5.61	190	0.02	0.16	2.85
Egg width (cm)	4.35	190	0.01	0.11	2.53
Egg shape index (%)	77.47	190	0.07	1.00	1.29
Egg volume (cm^3)	55.66	190	0.31	4.24	7.62
Egg mass loss until day 18 of incubation (g)	7.03	190	0.05	0.67	9.53
Egg mass loss until day 18 of incubation (%)	11.47	190	0.04	0.62	5.40
One day chick mass (g)	41.16	190	0.21	2.95	7.17
Relative chick share in the egg mass (%)	67.21	190	0.10	1.38	2.05
Both sexes					
Egg mass before incubation (g)	60.73	409	0.19	3.88	6.39
Egg length (cm)	5.60	409	0.01	0.16	2.86
Egg width (cm)	4.34	409	0.01	0.11	2.53
Egg shape index (%)	77.48	409	0.05	1.07	1.38
Egg volume (cm^3)	55.26	409	0.20	4.13	7.48
Egg mass loss until day 18 of incubation (g)	6.95	409	0.03	0.62	8.92
Egg mass loss until day 18 of incubation (%)	11.44	409	0.03	0.59	5.15
One day chick mass (g)	40.72	409	0.14	2.80	6.88
Relative chick share in the egg mass (%)	67.04	409	0.06	1.28	1.91

Table 1.
Mean values and variability of morphometric traits of eggs (chicks) which hatched chicks.

respectively, chick hatchability percentage out of the number of incubated (laid) eggs was 86.51 and 84.89%, respectively, and 90.83 and 90.09% out of the number of fertilized eggs. Embryo mortality was 8.73 and 9.17% (YF_{33}), while in the older flock (OF_{49}), it was 9.33 and 9.91%.

Detailed measurements of morphometric indicators of eggs which hatched female and male chicks (the most important egg category) were made. Their mean values and absolute and relative variability measures are given in **Table 1**, and the difference significance is given in **Table 2**.

In the younger flock (YF_{33}), average mass of eggs which hatched female chicks was 58.06 g, and 58.83 g was the mass of eggs which hatched male chicks (**Table 1**). Difference determined (−0.77 g) was not statistically confirmed

(P > 0.05). Correspondingly, in the older flock (OF_{49}), the average mass of eggs which hatched female chicks was smaller by 0.98 g (**Tables 1** and **2**). The difference was not statistically significant (P > 0.05). In YF_{33}, egg shape index which hatched female chicks was 78.18%, while of those which hatched male chicks, it was 78.15%, and the difference of 0.03 was not statistically significant (P > 0.05). In contrast to YF_{33}, in OF_{49} eggs which hatched male chicks had higher egg shape index (76.69–76.72%), but the difference (−0.03%) was not significant (P > 0.05). Egg volume, both in YF_{33} and OF_{49}, was greater in case of eggs which hatched male chicks (YF_{33} = 52.82and 3.51 cm^3; OF_{49} = 57.35 and 58.05 cm^3), differences calculated (−0.69 cm^3 and −0.70 cm^3) were not statistically confirmed (P > 0.05).

Indicators (traits)	$X_{ž}$–M_{xs}	Difference	Significance	$t_{exp.}$
Young parent flock (YF33) - sexes				
Egg mass before incubation (g)	58.06–58.83	−0.77	NS	1.738
Egg length (cm)	5.48–5.51	−0.03	NS	0.754
Egg width (cm)	4.29–4.30	−0.01	NS	0.697
Egg shape index (%)	78.18–78.15	0.03	NS	0.212
Egg volume (cm^3)	52.82–53.51	−0.69	NS	1.348
Egg mass loss until day 18 of incubation (g)	6.58–6.63	−0.05	NS	0.785
Egg mass loss until day 18 of incubation (%)	11.34–11.28	0.06	NS	0.757
One day chick mass (g)	38.80–39.57	−0.77	*	2.359
Relative chick share in the egg mass (%)	66.84–67.26	−0.42	NS	1.879
Old parent flock (OF49) - sexes				
Egg mass before incubation (g)	62.92–63.90	−0.98	NS	1.878
Egg length (cm)	5.71–5.73	−0.02	NS	1.085
Egg width (cm)	4.38–4.40	−0.02	NS	1.303
Egg shape index (%)	76.69–76.72	−0.03	NS	0.496
Egg volume (cm^3)	57.35–58.05	−0.70	NS	1.593
Egg mass loss until day 18 of incubation (g)	7.23–7.47	−0.24	*	2.547
Egg mass loss until day 18 of incubation (%)	11.48–11.68	−0.20	*	2.484
One day chick mass (g)	42.14–42.93	−0.79	*	1.984
Relative chick share in the egg mass (%)	66.98–67.16	−0.18	NS	1.543
Young and old parent flock YF33 and OF49) - sexes				
Egg mass before incubation (g)	60.30–61.23	−0.93	*	2.430
Egg length (cm)	5.59–5.61	−0.02	NS	1.261
Egg width (cm)	4.33–4.35	−0.02	NS	1.926
Egg shape index (%)	77.49–77.47	0.02	NS	0.188
Egg volume (cm^3)	54.91–55.66	−0.75	NS	1.837
Egg mass loss until day 18 of incubation (g)	6.88–7.03	−0.15	*	2.486
Egg mass loss until day 18 of incubation (%)	11.41–11.45	−0.06	NS	1.002
One day chick mass (g)	40.34–41.16	−0.82	**	2.988
Relative chick share in the egg mass (%)	66.90–67.21	−0.31	*	2.458
Parent flock age, young – old (YF33 and OF49)				
Egg mass before incubation (g)	58.41–63.38	−4.97	***	16.784
Egg length (cm)	5.49–5.72	−0.23	***	19.842
Egg width (cm)	4.29–4.39	−0.10	***	10.385
Egg shape index (%)	78.16–76.70	1.46	***	18.562
Egg volume (cm^3)	53.14–57.68	−4.54	***	13.264
Egg mass loss until day 18 of incubation (g)	6.60–7.34	−0.74	***	15.196
Egg mass loss until day 18 of incubation (%)	11.31–11.57	−0.26	***	4.551
One day chick mass (g)	39.15–42.51	−3.36	***	15.131
Relative chick share in the egg mass (%)	67.03–67.06	−0.03	NS	0.228

** means p<0.05; ** means p<0.01; *** means p<0.001.*

Table 2.
Difference significance of mean values of some morphometric traits of eggs which hatched chicks (YF_{33} and OF_{49}).

Eggs—chick sex	Flock age	*n*	r_{xy}	Correlation significance
Eggs which hatched female chicks	YF_{33}	118	0.261**	Weak
	OF_{49}	101	0.430***	Medium
Eggs which hatched male chicks	YF_{33}	100	0.107^{NS}	Very weak
	OF_{49}	90	0.498***	Medium
Total eggs which hatched	YF_{33}	218	0.188**	Very weak
either sex chick	OF_{49}	191	0.442***	Medium
Eggs which hatched female chicks	YF_{33} + OF_{49}	219	−0.286***	Weak
Eggs which hatched male chicks	YF_{33} + OF_{49}	190	−0.353***	Weak
Total eggs which hatched either sex chick	YF_{33} + OF_{49}	409	−0.314***	Weak

*** means p<0.01; *** means p<0.001.*

Table 3.
Phenotype correlation coefficients between egg mass of both flocks (YF_{33} and OF_{49}) and egg shape index.

In both age groups, female chicks had smaller mass (YF_{33} = 38.80–39.57 g; OF_{49} = 42.14–42.93 g), and determined differences were statistically relevant: $P < 0.05$ and $P < 0.01$, respectively. Relative share of the chick in the egg mass in both flocks was also greater in case of male chicks, but these differences were not statistically significant ($P > 0.05$). Regardless of the parent flock age, eggs which hatched female chicks had lower values of the observed morphometric traits, except for the egg shape index (77.49 – 77.47%), which was higher by 0.02% in eggs which hatched female chicks, but the difference determined was not statistically significant ($P > 0.05$).

Contrary to the chick's sex, parent flock's age had more significant effects on observed morphometric traits of both sexes (**Tables 1** and **2**). All observed morphometric indicators of both eggs and newly hatched chicks of both sexes were statistically considerably higher ($P < 0.001$) in OF_{49} than in the younger flock YF_{33}, except the relative chicken share in the egg mass, whereby the relative chicken share was also greater in OF_{49}; however, the obtained difference (−0.03%) was not statistically significant ($P > 0.05$). Egg shape index was higher in case of YF_{33} (78.16 – 76.70%), and the determined difference of 1.46% was statistically significant ($P < 0.001$).

Among all observed morphometric traits, the phenotype correlation (r_p) was calculated between the egg mass before the incubation period and the egg shape index as the most relevant indicator for the purpose of this study. Calculated values for both flocks and both sexes are given in **Table 3**.

There was a very weak, weak, and medium phenotype correlation between the egg mass before incubation and the egg shape index, and the correlation coefficients were statistically confirmed ($P < 0.01$; $P < 0.001$), except between the egg mass of those eggs which hatched female chicks and the egg shaped index in the younger flock YF_{33}, whereby the calculated coefficient (r_{xy} = 0.107) was not statistically confirmed ($P > 0.05$). Apart from the mentioned strength of the phenotype correlation, total correlation on the global level was found between the egg mass before incubation and the mass of the newly hatched chicks, that is, the correlation coefficient values were above 0.900.

4. Discussion

It is an established fact that the egg laying intensity grows with the age of the parent flock, that is, the rate of the egg fertilization and the chick hatchability grows up to a certain flock age, after which point it decreases. Most of the morphometric indicators (egg mass and newly hatched chicken mass in the first place) normally grow throughout the whole production cycle, which was confirmed by our study and the studies of numerous other authors who treated this matter. These fluctuations are more prominent in case of eggs which hatched male chicks.

Abudabos [9] in two broiler parent flocks (Cobb and Ross) and in parent flocks of different ages (26, 44, 32, and 36 weeks of age) report that the egg mass, relative egg mass loss until day 19 of incubation, newly hatched chicken mass, and the share (percentage) of the chick in the egg mass grow with the age in both parent flocks, while the percentage of fertilized eggs and chick hatchability decreases.

Embryo mortality is higher in case of older broiler parents, particularly in case of Cobb hybrid of 44 weeks of age, when the embryo mortality rate recorded was over 12%. Comparably, Ulmer-Franco et al. [8] report that the age of broiler parents of the Cobb 500 hybrids and egg mass have influence on incubation values of eggs for fertilization. With flock's growing age—from week 29 to week 59, egg mass increased from 53.8 to 71.3 g, relative egg mass loss until day 18 of incubation decreased from 12.8 to 11.9%, egg fertilization rate increased from 76.7 to 94.4%, while the chick hatchability out of the number of fertilized eggs decreased from 88.0 to 87.0%. Total embryo mortality was 10.6% (29 weeks old flock) and 9.4% (59 weeks old flock). Also in the Cobb 500 parent flock, 500 [1, 11] report statistically significant ($P < 0.001$) effect of age on the egg mass and newly hatched chicken mass increase, while the largest number of fertilized eggs was observed in the middle of the production cycle (97.05%), followed by the beginning of the cycle (96.09%), and the smallest was recorded in the final stage of the production cycle (93%). The chick hatchability out of the number of incubated and the number of fertilized eggs was also at its peak in the middle of the production cycle and amounted to 81.14 and 83.94%, respectively. Alsobayel et al. [12] report that the genotype (Arbor Acres, Cobb, and Ross) and the age of the broiler parents (30–35, 40–45, 50–55 weeks) have effects on the average egg mass and one-day chicken mass and also on the share of the chicken in the egg mass.

Depending on the type of hybrid (genotype), egg mass fluctuated between 63.7 and 64.7 g, one-day-old chicken mass between 44.5 and 45.4 g, and the share of chicken in the egg mass varied from 68.1 to 69.7%. In all three hybrids, the growth of egg mass (59.3–68.9 g) and chick mass (41.4–48.4 g) simultaneously with the growth of the flock's age was recorded, while the share of the chick in the egg mass was largest in the last weeks (69.7%) and smallest in the middle of the production cycle (687%). Similar chicken share in the egg mass in 10 different broiler hybrid parents—breeds (between 66.9 and 70.4%) is reported by [7]. Furthermore, loss of egg mass up to day 18 of incubation varied from 12.1 to 13.7%.

Pinchasov [3] makes a slightly different conclusion compared with previously mentioned researchers, which is that effects of laying hens age are less significant for the chick mass than the egg mass which has a considerably greater effect on the one-day-old chick mass. In line with these conclusions, [5] point out that physical characteristics of eggs (egg mass, egg shell thickness and porosity, egg shape index) play an important role in the embryo development process and hatchability success rate. Effects of egg mass on the newly hatched chicken mass, embryo mortality, and percentage of the chicken in the egg mass (progression of the egg mass loss during incubation period) are reported by [6] in case of the hybrid Ross SL 2000 parent flock, raised from 35 to 49 weeks of age. Light eggs (average mass 54.59 g) hatched chicken of 38.11 g of average mass, medium eggs (58.89 g) hatched the chicks of 40.74 g, and heavy eggs (63.10 g) hatched the chicks of 43.18 g of average mass. Loss due to embryo mortality was greater in light (7.83%) and heavy eggs (7.90%), in comparison with eggs of medium weight (6.67%). Furthermore, heavy (large) eggs had the greatest egg mass loss during incubation period. i.e., the smallest eggs had the largest share of the chick mass in the egg mass (69.81%), followed by the eggs of medium weight (69.17%), while the largest eggs had the smallest share (68.43%). Wilson [4, 6, 10] report the relative share of the chick mass in the egg mass fluctuating from 67 to 70%, from 62 to 76%, and from 68.43 to 69.81%, respectively. Similar conclusions related to effects of age and the egg weight group on incubation values in the Hubbard Classic broiler parents were made by [13, 14]. In the light egg weight group (average mass 63.09 g), average mass of newly hatched male chicks was 43.33 g; in the medium weight group (68.85 g), it was 48.40 g; and in the heavy weight group (74.81 g), it was 52.36 g. In case of female chicken, the average mass was 43.29, 48.24, and 52.38 g, respectively. The relative share of the chicken mass in the egg mass was 69.97, 70.22, and 70.38% (male chicks), and 69.84, 70.12, and 70.17% (female chicks).

In an interesting research, [5, 15] indicate considerable effects of the egg shape index on incubation indicators and point out that eggs of anomalous shape should not be used for incubation because they prevent normal embryo development which results in a higher embryo mortality rate during incubation period. This conclusion was confirmed by [16] who studied mechanical (physical) and incubation values of eggs of two hen breeds (Naked Neck and Sombor kaporka) raised in semi-intensive keeping system. They report egg shape index of 71.01 and 72.04%, respectively, for the two breeds and 73.61 and 76.68% for the relative share of the chicken in the egg mass. Abanikannda and Leigh [17] report higher egg shape index of eggs which hatched male chicks (Anak and Marshall hybrids) than in eggs which hatched female chicks (75.25 and 74.53%; 76.27 and 76.00%). Regarding the eggs coming from the Ross hybrid, egg shape index was 76.09% (male chicks) and 76.41% (female chicks).

Based on presented and discussed results of cited authors, we can conclude that most of them studied or reported effects of nongenetic factors on incubation values and morphometric egg indicators and production of one-day-old chicken of both sexes of different genotypes (hybrids) of broiler parents. This is understandable because hybrids of both sexes are used for the broiler meat production. However, when it comes to light hybrids egg incubation, male chicks are killed, while females are used for breeding and raising, i.e., for the commercial production of eggs for consummation.

Kocevski et al. [25, 26] studied effects of age on the mass, strength, fertility, and hatchability of eggs in two light line hybrids (ISA Brown and DeKalb White) on production of eggs for consummation and for fertilization.

Egg mass was considerably affected ($P \leq 0.05$) by age, but not by the line (genotype), although eggs of the (commercial) ISA Brown line were somewhat heavier than those of the DeKalb White line. The heaviest egg mass was that of older poultry, while eggs laid by younger hens had smaller mass. In younger commercial laying hens and parent […] flocks laying hens produced eggs with stronger shells than those laid by older hens. Average chicken hatchability during the 6 months period of egg production was 70.50% (Isa Brown) and 73.64% (DeCalb). Zita et al. [29] report egg mass to grow with hen's age in three genotypes (ISA Brown, Hisex Brown, and Moravia BSL), while the egg shape index decreased.

Average egg mass of the ISA Brown laying hens was 54.00 g at the beginning of the production cycle, 62.78 g in the middle, and 63.42 g at the end of the production cycle (54–60 weeks of age), while the egg shape index decreased from 78.52 to 76.64%, and 75.09%. Duman et al. [30] are of opinion that the standard egg shape index of commercial laying hens fluctuates between 72.2 and 75.9% (average value –74.3%), of the pointy shape between 68.0 and 71.9% (average 71.0%), while the egg shape index of round eggs ranged from 76.1 to 82.3% (average 78.8%).

Furthermore, the authors make a conclusion that the egg shape index affects certain consummation egg qualities and report certain phenotype correlation between these qualities.

Results obtained in our research partly correspond with conclusions of previous authors who primarily studied different genotypes of broiler parents. Research most similar to ours was conducted by [27] with one of the aims to determine chick's potential sex before egg incubation (Super Nick White Layer) using morphometric measurements of eggs (weight, length, width, shape index, volume). Their conclusion is that length, width, shape index, and volume before incubation period have certain effect on the future chick sex, especially egg shape index and egg width and length.

In case of 54 weeks old laying hens, egg shape index was 71.1% (male), 75.5% (female), and 75.3% (both sexes), while the average egg mass was 60.8 g (male), 60.9 g (female), and 60.8 g (both sexes). Two-hundred forty-four (244) chicks of both sexes were hatched out of 300 incubated eggs (the hatchability rate was 81.33%). Terčič and Pestotnik [28] recorded egg incubation values of the hybrid Prelux-G parent younger (24 weeks) and older (65 weeks) flocks. Older parent flock produced heavier eggs (66.63–56.77 g), than the younger one, had higher relative egg mass loss up to week 18 of incubation (11.26–11.14%), male and female chicks were heavier, embryo mortality was higher (13.52–11.36%), while the chick hatchability out of the number of incubated and fertilized eggs was at a lower level. Male-female chick rate was 1.09 in the younger flock and 1.16 in the older flock. In both flocks, male chicks were slightly heavier than the female. In general, our results are to a large extent compatible with results obtained by [27, 28] and even [24]. Narushin [24] reports an average egg shape index of 75.20% (69.70–80.10%) and egg volume of 60.19 cm^3 (52.00–70.40 cm^3) of eggs laid by the 65-week-old Hy-Line Brown hens, regardless of the chick sex.

These results agree with those of [23] who reports the egg length of 5.90 cm, width 4.40 cm, and egg shape index around 75.0%. Additionally, [31–33] analyzed morphometric indicators of the wild birds' eggs with a purpose to determine possible bird sex before the incubation period and reached similar but questionable results.

Certain authors report phenotype correlation between the parent flock's age in hens and even other types of poultry, laying intensity, hatching egg mass, newly hatched offspring mass, and the relative share of the chick in the egg mass. Skewea et al. [2] point out that the egg mass increases with the age of the parent flock in domestic birds and also that eggs of different sizes (mass) have different physical (external) and chemical (internal) characteristics which affect the hatchability percentage out of the number of fertilized eggs and the quality of hatched chicks. Explicitly, one-day-old chick mass is tightly related with the preincubation egg mass, that is, there is a strong correlation between them. Furthermore, heavier chicks have smaller yolk, while lighter chicks have a larger yolk (food reserve), which enables them to survive a longer period of time before they can obtain exogenous food source.

In line with these results, Suarez et al. [35] report total correlation between the age and the egg mass of Arbor Acres broiler parents of 29–57 weeks of age and medium phenotype correlation between the age and chick mass, and the determined correlation coefficient was statistically significant at $P < 0.001$. Farooq et al. [36] report statistically significant ($P < 0.05$) correlation coefficient ($r_p = 0.496$) between the egg mass and one-day chick mass of the pure breed Rhode Island Red. By calculating the phenotype correlation coefficients between the egg mass, chick mass, and the hatchability percentage out of the number of incubated and fertilized eggs, these authors have also confirmed statistically significant correlation ($P < 0.05$), which is to a large extent in line with our results.

In both ethical and economic contexts, as an addition to this discussion, we are including here the studies of [18, 19], who used male chicks of the ISA Brown and Hy-Line hybrids in organic production of broiler meat, where the fattening period lasted 49 and 90 days, and 51 days, and obtained quality organic broiler meat. Gerken et al. [20–22] point out that from the humane and welfare aspect, it is not economically justified to use male chicks of all light line hybrids for fattening in intensive broiler meat production, but in extensive and semiextensive conditions, with a prolonged fattening period, it is possible to produce good-quality meat with higher protein content and lower percent of abdominal fat. Finally, Weissmann et al. [22] report greater average mass of newly hatched male chicks, than of female chicks by 0.5, 2.1, and 0.02 g in three parent flocks of the light type Lohmann—Germany.

5. Conclusion

Based on the research undertaken with an aim to establish effects of the light line hybrid ISA Brown parent flock's age on incubation values of eggs (fertilization and chick hatchability) and morphometric indicators (pre incubation egg mass, length, width, and egg shape index, absolute and relative egg mass loss until day 18 of incubation, hatched chicken mass and relative share of the chick in the egg mass) and their possible effects on the sex of the hatched chicks, two conclusion can be made. First, in comparison with the older flock (OF_{49}), the younger flock (YF_{33}) demonstrated better incubation values of eggs, and all its morphometric indicators were lower, with the exception of the egg shape index which was statistically significantly greater ($P < 0.001$) by 1.46% in the YF_{33}. Second conclusion is that the eggs which hatched female chicks (YF_{33} + OF_{49}) had lower values of observed morphometric traits than those with male chicks, except the egg shape index.

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